bore must not be so narrow that the consequent resistance to flow exceeds the capability of the well pump, and the bore must be wide enough to accommodate suspended particles. The tube must not kink or fracture at low temperatures. It should be sufficiently insulated to prevent freezing during normal operation and it should tolerate inadvertent freezing.

This work was done by Michael Hecht and Frank Carsey of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-40031

Real-Time Simulation of Aeroheating of the Hyper-X Airplane

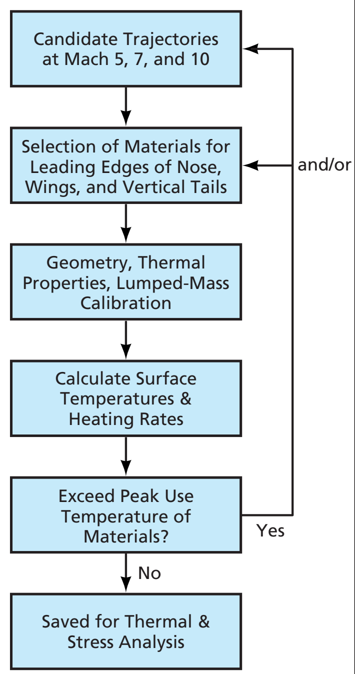
Computational simulations are expected to provide guidance for initial design choices.

Dryden Flight Research Center, Edwards, California

A capability for real-time computational simulation of aeroheating has been developed in support of the Hyper-X program, which is directed toward demonstrating the feasibility of operating an air-breathing ramjet/scramjet engine at mach 5, mach 7, and mach 10. The simulation software will serve as a valuable design tool for initial trajectory studies in which aerodynamic heating is expected to exert a major influence in the design of the Hyper-X airplane; this tool will aid in the selection of materials, sizing of structural skin thicknesses, and selection of components of a thermal-protection system (TPS) for structures that must be insulated against aeroheating.

The Hyper-X airplane will include an inlet/combustor/nozzle assembly attached to an airframe. The forebody of the inlet will consist of a leading edge and a tungsten ballast. Movable wings and vertical tail rudders will give the autonomous airplane controllability. Mounted inside the airframe will be all the active systems needed to fly and to demonstrate the ramjet/scramjet engine. The fuel-burning and flight hardware will be instrumented to collect and telemeter flight data.

Because of the short duration of flight, critical areas on the airframe TPS will be limited to the leading edges on the nose, cowl, and side walls of the inlet and the horizontal wings and vertical tails. In addition to other aeroheating effects, gap heating is expected to occur at horizontal wing roots, and at vertical rudder roots by amounts that will vary with movement of the rudders.



The **Computational Simulation of Aeroheating** is one of several real-time simulations used in initial design studies. This simulation can be used to eliminate flight trajectories that would give rise to local temperatures in excess of structural-design temperature limits.

The present capability for real-time computational simulation of aeroheating makes it possible to predict temperature as a function of time at critical heating locations on the Hyper-X airplane. Simulations of this type are used extensively to select acceptable flight trajectories by eliminating ones for which structural-design temperature limits would be exceeded (see figure). Other real-time simulations can be performed, using software modules that enable evaluation of other aspects of operation and design, including aerodynamics, reaction control system, flight guidance, and airplane structures. At speeds in excess of mach 2, aeroheating is considered important enough to affect design parameters, so that it becomes necessary to include a software module for simulation of aeroheating.

Thus far, a mathematical submodel of a nose with a solid carbon/carbon leading edge has been incorporated into the mathematical model used in the simulation of aeroheating. This submodel model includes 14 temperature nodes. Other submodels of aeroheating of the tail rudder and the leading edges of the horizontal and vertical tails were undergoing development at the time of reporting the information for this article.

This work was done by Les Gong of **Dryden Flight Research Center**. *For further information, contact the Dryden Commercial Technology Office at (661) 276-3143.*
DRC-98-76

Using Laser-Induced Incandescence To Measure Soot in Exhaust

This system incorporates several improvements over prior LII soot-measuring systems.

John H. Glenn Research Center, Cleveland, Ohio

An instrumentation system exploits laser-induced incandescence (LII) to measure the concentration of soot particles in an exhaust stream from an engine, furnace, or industrial process that burns hydrocarbon fuel. In comparison with LII soot-concentration-measuring systems that have been described in prior *NASA Tech Briefs* articles, this system is more complex and more capable.

Like the other systems, this system includes a pulsed laser and associated op-